Correlations between Cervical Vertebral Maturation (CVM) and Dental Development in Thai Cleft Patients

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Objective: *To examine correlations between cervical vertebral maturation stages (CVMs) and dental development stages, and cervical vertebral maturation (CVM) stage 6 and completion of root formation of mandibular third molar in Thai cleft patients.*
Material and Method: *Lateral cephalograms of 366 cleft subjects aged 7-9 years were assessed for CVMs using Baccetti method. Calcification stages of all left mandibular teeth within each CVMs were assessed from panoramic films using Demirjian method.*
Results: *Spearman rank correlation coefficients comparing CVMs and teeth were 0.51-0.79 ($p<0.001$). Second molar had the highest and central incisor had the lowest correlations. In CVMs 6, 2.9% of third molars had completed root formation. However, only CVMs 6 could be predicted from third molar stage G that had a high likelihood ratio (30.94).*
Conclusion: *Dental development was highly correlated with CVM in clefts. Third molar stage G could predict completed growth of mandible in individual patients, but it should be combined with other maturation indicators.*

Keywords: *Cervical vertebral maturation, Cleft patients, Dental development*

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Cleft patients usually have skeletal problems, especially maxillary hypoplasia[1]. Some of cleft patients require growth modification or orthognathic surgery to improve this skeletal problem[2]. Favorable outcomes of orthodontic and/or surgical correction of dento-facial deformities are related to age-specific timing of such clinical intervention[3]. Thus, it is important to know the stage of maturation of patient[4]. There are several methods to assess growth status such as chronological age, dental development and development of secondary sexual characteristics[5]. Chronological age is an unreliable method for assessment skeletal maturity[6]. The cervical vertebral maturation (CVM) method has proved to be effective to assess skeletal maturity[7]. Dental development has been also investigated as a potential tool for predicting skeletal maturity[8,9]. Many previous studies found that there is correlation between CVM and dental development in non-cleft patients[4,10,11]. However, dental development in cleft patient is usually delayed[12,13]. Thus, the different results are expected in correlations between CVM and dental development in cleft patients compared with non-cleft patients. However, no previous study correlates relationships between CVM and dental development in Thai cleft patients.

The expected benefit was the ability to use identifiable stages of dental development provided by routine dental panoramic radiographs as an alternative to the requirement of cephalometric lateral radiographs for CVMs assessments. This alternative would reduce radiation exposure, cost and time required for checking.

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Objective

To examine correlations between cervical vertebral maturation stages and stages of dental development as well as between CVMs 6 and completion of root formation of third molar.

Material and Method

Subjects

The materials used in this study consisted of

data records, lateral cephalometric films and panoramic films of cleft patients who were registered for treatment at the Department of Orthodontics, Faculty of Dentistry, Khon Kaen University from the year 1993 to 2013.

Inclusion criteria:

1) All types of cleft patients.

2) Patients aged seven to 19 years.

3) Cephalometric and panoramic film must be available and taken on the same day.

4) There was availability of treatment record and high quality of radiographs sufficient to interpret.

Exclusion criteria:

1) Medical diseases that affect development of mandibular teeth and cervical vertebra.

2) Syndromic cleft patients.

3) Previous history of orthognathic surgery or maxillofacial trauma.

4) Missing any mandibular teeth on both sides, except third molars.

5) Impacted mandibular teeth.

CVM assessment

The lateral cephalograms were assessed for CVM stage using Baccetti method[14], which consists of six scales including:

Cervical stage 1:

The lower borders of C2 to C4 are flat. The bodies of both C3 and C4 are trapezoid in shape.

Cervical stage 2:

The lower border of C2 is concave. The bodies of C3 and C4 are still trapezoid in shape.

Cervical stage 3:

Concavities at the lower borders of both C2 and C3 are presented. The bodies of C3 and C4 may be either trapezoid or rectangular horizontal in shape.

Cervical stage 4:

Concavities at the lower borders of C2, C3 and C4 now are presented. The bodies of both C3 and C4 are rectangular horizontal in shape.

Cervical stage 5:

The lower borders of C2, C3 and C4 still are concave. At least one of the bodies of C3 and C4 is square in shape. If not, the body of the other cervical vertebra still is rectangular horizontal.

Cervical stage 6:

The concavities at the lower borders of C2, C3 and C4 still are evident. At least one of the bodies of C3 and C4 is rectangular vertical in shape. If not, the body of the other cervical vertebra is square.

Dental development assessment

Dental development was assessed by observing dental calcification of left mandibular central incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar and third molar or of right-side if any left-side tooth was missing from panoramic film. The standard scales for rating dental calcification was based on Demirjian[15].

Stage A:

Cusp tips begin to calcify, but no fusion of these calcified points are presented.

Stage B:

Fusion of the calcified points and outline of occlusal surface can be identified.

Stage C:

Enamel formation is completed at the occlusal surface. Dentine begins to form. The pulp chamber has a curved shape at the occlusal border.

Stage D:

Crown formation is completed at the cementoenamel junction level. Root begins to form. In uniradicular teeth, pulp chamber has curved at the superior border and is concave towards the cervical region. In molars, pulp chamber has a trapezoidal form.

Stage E:

In uniradicular teeth, root length is less than the crown height. The walls of the pulp chamber form straight lines. In molars, initial formation of bifurcation is seen.

Stage F:

Root length is equal to or greater than the crown height. Apex ends in a funnel shape. In uniradicular teeth, the walls of the pulp chamber form an isosceles triangle shape. In molars, the development of bifurcation is adequate to identify the roots.

Stage G:

The walls of the root canal are now parallel and its apical end is still partially opened (distal root in

molars).

Stage H:

The apical end is completely closed (distal root in molars); the periodontal membrane has a uniform width around the root and the apex.

Assessors

All lateral cephalometric and panoramic films, patient's name, hospital number, gender and age were masked. Fifty cephalometric and panoramic films were selected randomly to evaluate examiner reliability of determining cervical vertebral and dental maturation stage. Vertebral body tracings and dental development were evaluated by two examiners and repeated by each assessor with one month separation.

Data analysis

All statistical analyses were performed with the Statistical Package for Social Science version 17.0 for Windows (SPSS, Inc., Chicago, Illinois, USA). Descriptive statistics were used for demonstrating the distribution of subjects for each cervical bone stage. The intra- and inter-observer reliability of both CVM and dental development were evaluated by the Kappa statistic. Spearman rank correlation and 95% confidence intervals (CIs) were used to find the correlation between CVM and dental development. The dental development for each cervical stage was presented in percentage distribution. Positive Likelihood ratio was used to evaluate diagnostic performance of dental maturation stages for identifying of the skeletal maturation stages.

Results

Total 366 films used were consisted of 183 female films and 183 male films. The distribution of films for each CVM stage was shown in Table 1.

Good to very good degrees of intra- and inter-assessor reliabilities were found in assessment of CVM and dental development. Kappa values with 95% CI for CVM stage assessment were: first assessor = 0.80 (0.68-0.92), second assessor = 0.88 (0.78-0.98) and inter-assessor = 0.83 (0.71-0.94) for first assessment and 0.76 (0.62-0.90) for second assessment. Kappa values with 95% CI for dental development stage assessment were: first assessor = 0.87 (0.83-0.91), second assessor = 0.80 (0.75-0.85) and inter-assessor = 0.81 (0.76-0.85) for first assessment and 0.80 (0.75-0.85) for second assessment.

Spearman rank correlation coefficients between cervical vertebral and dental development stages for each tooth are shown in Table 2.

All correlations between cervical vertebral and dental development stages gave *p*-values <0.001 with corresponding confidence intervals of 0.43-0.58 and 0.75-0.83, respectively. The sequence from lowest to the highest correlation coefficient was central incisor, first molar, lateral incisor, canine, second premolar, first

Table 1. The distribution of subject's film for each CVM stage

Stage of cervical bone	Number		
	Female	Male	Total
CVMs 1	53	49	102
CVMs 2	27	41	68
CVMs 3	30	35	65
CVMs 4	34	17	51
CVMs 5	23	22	45
CVMs 6	16	19	35
Total	183	183	366

Table 2. Spearman rank correlation coefficients between cervical vertebral stage (CVMs 1 to 6) and dental development stages (A to H) for each tooth

Tooth	Number of subjects	Correlation coefficient	*p*-value	95% confidence intervals
Central incisor	366	0.51	<0.001	0.43-0.58
Lateral incisor	366	0.65	<0.001	0.59-0.71
Canine	366	0.76	<0.001	0.71-0.80
First premolar	366	0.77	<0.001	0.72-0.81
Second premolar	366	0.76	<0.001	0.71-0.80
First molar	366	0.65	<0.001	0.58-0.70
Second molar	366	0.79	<0.001	0.75-0.83
Third molar	230	0.78	<0.001	0.72-0.82

premolar, third molar and second molar.

The percentage distributions of calculation stages of individual teeth at each CVM stage are shown in Table 3 to 8.

In CVMs 1, the most frequently observed dental development stage was D (crown formation completed) for the second molar (66.7%).

In CVMs 2, the most significant occurrence was of canines in stage F (root length about half completed) (63.2%).

In CVMs 3, 67.7% of canines were in stage F. Complete closures of root apices of central incisor and first molar were observed in most subjects (83.1% of central incisors and 73.8% of first molars).

In CVMs 4, the highest percentage was of second molars in stage F. Most of subjects had completed root formation (stage H) of central and lateral incisors and first molar.

In CVMs 5, central and lateral incisors, and first molars had completed development (stage H). All canines were closely approaching stage H, followed by premolars and second molars with no third molars. Approximately one-third of third molars were in stage D (crown formation completed).

In CVMs 6, all central and lateral incisors and first molars were in stage H (completed root formation) and most second molars had nearly completed root formation.

In the present study, positive Likelihood ratio (LHR) was used to investigate diagnostic performance of dental maturation for skeletal maturation identification. The highest positive LHR values in each CVM stage are shown in Table 9.

LHR above 10 indicates moderately strong diagnostic property[16]. In CVMs 1 to 5, none of these values were close to 10. In contrast with CVMs 6, LHR values of more than 10 were found in third molar stage G

Table 3. Percentage distribution of calcification stages of individual teeth at CVMs 1

Stage	Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar	Third molar
A								23.5
B								6.9
C					1			6.9
D			1	2	15.7		66.7	
E	1	3.9	35.5	63.7	62.7		23.5	
F	15.7	41.2	55.9	31.4	18.6	28.4	7.8	
G	41.2	36.3	4.9	1.0	1	52	2	
H	41.2	18.6	2.9	2	1	19.6		

n = 102 for central incisor to second molar and n = 34 for third molar. Blank cells represent zero percentage

Table 4. Percentage distribution of calcification stages of individual teeth at CVMs 2

Stage	Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar	Third molar
A								22.1
B								11.8
C							1.5	7.4
D			1.5		7.4		38.2	4.4
E			20.6	44.1	47.1		30.9	
F	13.2	26.5	63.2	44.1	42.6	17.6	27.9	
G	20.6	26.5	13.2	10.3	1.5	36.8	1.5	
H	66.2	47.1	1.5	1.5	1.5	45.6		

n = 68 for central incisor to second molar and n = 31 for third molar. Blank cells represent zero percent

Table 5. Percentage distribution of calcification stages of individual teeth at CVMs 3

Stage	Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar	Third molar
A								20
B								20
C								24.6
D					3.1		20	9.2
E			4.6	20	26.2		27.7	
F	6.2	12.3	67.7	52.3	55.4	4.6	46.2	
G	10.8	20	20	20	7.7	21.5	6.2	
H	83.1	67.7	7.7	7.7	7.7	73.8		

n = 65 for central incisor to second molar and n = 48 for third molar. Blank cells represent zero percent

Table 6. Percentage distribution of calcification stages of individual teeth at CVMs 4

Stage	Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar	Third molar
A								9.8
B								9.8
C								49
D							2	7.8
E				2	9.8		5.9	3.9
F			21.6	35.3	47.1		54.9	3.9
G	2	2	37.3	15.7	15.7	5.9	21.6	
H	98	98	41.2	47.1	27.5	94.1	15.7	

n = 51 for central incisor to second molar and n = 43 for third molar. Blank cells represent zero percent

Table 7. Percentage distribution of calcification stages of individual teeth at CVMs 5

Stage	Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar	Third molar
A								
B								2.2
C								20
D								31.1
E							2.2	17.8
F			2.2	2.2	11.1		15.6	20
G			2.2	17.8	11.1		33.3	2.2
H	100	100	95.6	80	77.8	100	48.9	

n = 45 for central incisor to second molar and n = 42 for third molar. Blank cells represent zero percent

Discussion

The closeness of correlation between skeletal and dental maturity in non-clefts is controversial. Some studies have found low correlations between dental and skeletal maturity[17,18] whilst others have found high correlations[19,20,21] and concluded that dental

Table 8. Percentage distribution of calcification stages of individual teeth at CVMs 6

Stage	Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar	Third molar
A								
B								
C								8.6
D								8.6
E								34.3
F				2.9	8.6		5.7	22.9
G			8.6	2.9			11.4	14.3
H	100	100	91.4	94.3	91.4	100	82.9	2.9

n = 35 for central incisor to second molar and n = 32 for third molar. Blank cells represent zero percent

Table 9. The highest positive Likelihood ratio (LHR) for dental development stages for diagnosis of the skeletal maturation stages (n = 366)

CVM stage	The highest LHR for developmental stages of tooth at each CVM stage	
	Developmental stages of tooth	LHR value
1	Second premolar stage D	5.91
2	Canine stage D	4.38
3	First premolar stage G	2.41
4	Second premolar stage G	4.12
5	Canine stage H	4.95
6	Third molar stage G	30.94

development could be used to identify the stage of the skeletal maturation[9,19,21]. This controversial conclusion may be due to differences in the assessment methods[10]. In the present study of cleft patients, there were high correlations between cervical vertebral maturation and dental calcification stages for all teeth with correlation coefficients = 0.51-0.79 (p<0.001). Among different non-cleft studies, the teeth that had the highest correlations with CVM varied, such as canine[10,19], second premolar[22] and second molar[4,9,10]. In this cleft study, the tooth that had the highest correlation with cervical vertebral maturation was the second molar (r = 0.79). A few studies have reported that third molars had the lowest correlation with CVM in non-cleft subjects[4,9]. In contrast to the present study, the correlation between the third molar and cervical vertebral maturation stage was high (r = 0.78), while the central incisor had the lowest correlation coefficient (r = 0.51). In addition, lateral incisor and first molar also had low correlations because their root apexes were more often completely closed at an early age.

The mandibular teeth, which may be appropriate candidates to match with different CVM stages (according to the highest percentage distribution), were second molar stage D in CVMs 1, canine stage F in CVMs 2, canine stage F combined with apical closure of central incisor and first molar in CVMs 3, second molar stage F combined with completed root formation of central incisor, lateral incisor and first molar in CVMs 4 and second molar stage H combined with central, lateral incisor and first molar which root apex were completely closed (stage H) in CVMs 5. Percentage of third molars completed root formation (stage H) in CVMs 6 was 2.9. It is likely that the third molar stage H could happen sometime beyond completion of skeletal maturation as judged by the presence of CVMs 6 and varying chronological age. Notice that in CVMs 6 the third molar should be included because central incisors to second molars had almost completed root formation, whilst one-third of the third

molars were still developing in stage E. The third molar development would be expected to have a high correlation with CVMs 6.

The likelihood ratio (LHR) is the best measure of a screening test[23] because the LHR indicates how much a given dental maturation stage changes the odds of having a given CVM stage[24]. In CVMs 1 to 5, there was no tooth that had positive LHR greater than 10. This showed that dental maturation of each tooth could not clearly identify skeletal maturity in CVMs 1 to 5. In contrast with CVMs 6, the LHRs values of more than 10 were found in third molar stage G (LHR = 30.94). This result suggests that the third molar stage G could be the diagnostic parameter equivalent to CVMs 6.

Clinical application of dental development for determining skeletal maturity

In the present study, the development of third molars in stage G according to Demirjian's method (nearly complete apical closure) was useful for identifying CVMs 6 because of its moderately high LHR. However, for possible clinical application, third molar stage G may not be ideal to identify timing for orthognathic surgery because it is probable that patients are just reaching or have recently reached this CVMs 6. Moreover, even in CVMs 6, the mandible can continue some growth. In this study, most third molars had still not reached completion of root formation in CVMs 6. Therefore, when the third molar development is at stage G as seen on a radiograph, at least a starting point of CVMs 6 is occurring. When the root apices of third molar are completely closed, this serves as a screening tool indicating that the patient may probably have completed growth of the mandible. At this time, as a double check, the individual patient should be followed-up with hand-wrist film or serial cephalometric tracing superimposition to confirm the completion of growth of mandible, as is desirable for patients being prepared for mandibular set-back surgery[25].

Conclusion

There was significant correlation between cervical vertebral maturation stages and development of mandibular teeth in Thai cleft patients. The tooth showing the highest correlation was the second molar whilst the central incisor had the lowest correlation.

In CVM stage 6, a majority of the third molars were still developing with start of root formation. Only a few of third molars had completed root formation. Identification of developing skeletal maturity from CVM stages 1 to 5 could not be obtained from observing stages of dental maturation. The nearing completion of the third molar apical closure stage showed the best performance to identify CVMs 6 because of its moderately high likelihood ratio value. For clinical implication, the dental development should be combined with other indicators to identify completed growth of the mandible in the individual patient.

What is already known on this topic?

All previous research on the correlation between skeletal and dental maturity was studied in non-cleft patients. Some studies have found high correlation and concluded that dental development could be used to identify the skeletal maturational stage.

What this study adds?

This is the first study in Thai patients and in cleft patients for whom the results showed there was correlation between skeletal and dental maturity in cleft patients. This study included positive likelihood ratio (LHR) to investigate diagnostic performance of dental maturation for skeletal maturation identification. Third molar stage G could predict completed growth of the mandible.

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Potential conflicts of interest

None.

References

1. Wyszynski DF. Cleft lip and palate: from origin to treatment. New York: Oxford university press; 2002.
2. Cheung LK, Chua HD. A meta-analysis of cleft maxillary osteotomy and distraction osteogenesis. Int J Oral MaxillofacSurg 2006; 35: 14-24.
3. Wolford LM, Stevao EL. Correction of jaw deformities in patients with cleft lip and palate. Proc (BaylUniv Med Cent) 2002; 15: 250-4.
4. Basaran G, Ozer T, Hamamci N. Cervical vertebral and dental maturity in Turkish subjects. Am J OrthodDentofacialOrthop 2007; 131: 447-20.
5. Bishara SE. Textbook of Orthodontics. Philadelphia: Elsevier; 2001.

6. Grave K, Townsend G. Cervical vertebral maturation as a predictor of the adolescent growth spurt. Aust Orthod J 2003; 19: 25-32.
7. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. Am J Orthod Dento facial Orthop 1995; 107: 58-66.
8. Anderson DL, Thompson GW, Popovich F. Interrelationships of dental maturity, skeletal maturity, height and weight from age 4 to 14 years. Growth 1975; 39: 453-62.
9. Mittal SK, Singla A, Virdi MS, Sharma R, Mittal B. Co-relation between determination of skeletal maturation using cervical vertebrae and dental calcification stages. Internet J Forensic Sci 2011; 4: 1-13.
10. Chen J, Hu H, Guo J, Liu Z, Liu R, Li F, et al. Correlation between dental maturity and cervical vertebral maturity. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010; 110: 777-83.
11. Heravi F, Imanimoghaddam M, Rahimi H. Correlation between cervical vertebral and dental maturity in Iranian subjects. J Calif Dent Assoc 2011; 39: 891-6.
12. Tan EL, Yow M, Kuek MC, Wong HC. Dental maturation of unilateral cleft lip and palate. Ann Maxillofac Surg 2012; 2: 158-62.
13. Loevy HT, Aduss H. Tooth maturation in cleft lip, cleft palate, or both. Cleft Palate J 1988; 25: 343-7.
14. Baccetti T, Franchi L, McNamara JA. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. Semin Orthod 2005; 11: 119-29.
15. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. Hum Biol 1973; 45: 211-27.
16. Deeks JJ, Altman DG. Diagnostic tests 4: likelihood ratios. BMJ 2004; 329: 168-9.
17. Lewis A, Garn S. The relationship between tooth formation and other maturational factors. Angle Orthod 1960; 30: 70-7.
18. Tanner JM. Growth at adolescence. 2nd ed. Oxford, UK: Blackwell Scientific Publications; 1962.
19. Krailassiri S, Anuwongnukroh N, Dechkunakorn S. Relationships between dental calcification stages and skeletal maturity indicators in Thai individuals. Angle Orthod 2002; 72: 155-66.
20. Sierra AM. Assessment of dental and skeletal maturity. A new approach. Angle Orthod 1987; 57: 194-208.
21. Uysal T, Sari Z, Ramoglu SI, Basciftci FA. Relationships between dental and skeletal maturity in Turkish subjects. Angle Orthod 2004; 74: 657-64.
22. Rozylo-KalinowskaI, Raczka A, Kalinowski P. Relationship between dental age according to Demirjian and cervical vertebrae maturity in Polish children. Eur J Orthod 2011; 33: 75-83.
23. Greenhalgh T. How to read a paper. Papers that report diagnostic or screening tests. BMJ 1997; 315: 540-3.
24. Perinetti G, Contardo L, Gabrieli P, Baccetti T, Di Lenarda R. Diagnostic performance of dental maturity for identification of skeletal maturation phase. Eur J Orthod 2012; 34: 487-92.
25. Houston WJ. Relationships between skeletal maturity estimated from hand-wrist radiographs and the timing of the adolescent growth spurt. Eur J Orthod 1980; 2: 81-93.

การศึกษาความสัมพันธ์ระหว่างการเจริญเติบโตของกระดูกต้นคอและพัฒนาการของฟันในผู้ป่วยโรคปากแหว่งเพดานโหว่ไทย

ปฐมพร จงจรวยสกุล, ทัศนีย์ วังศรีมงคล, พูนศักดิ์ ภิเศก, อารยา ภิเศก, มนเทียร มโนสุดประสิทธิ์

วัตถุประสงค์: เพื่อหาความสัมพันธ์ระหว่างระยะของการเจริญเติบโตของกระดูกต้นคอกับการพัฒนาการของฟัน และการเจริญเติบโตของกระดูกต้นคอในระยะที่ 6 กับการสร้างรากเสร็จสมบูรณ์ของฟันกรามล่างซี่ที่ 3 ในคนไทยที่เป็นปากแหว่งเพดานโหว่

วัสดุและวิธีการ: ใช้ภาพถ่ายรังสีกะโหลกศีรษะด้านข้างของผู้ป่วยปากแหว่งเพดานโหว่อายุ 7 ถึง 19 ปี จำนวน 366 ภาพ ประเมินระยะต่างๆ ของการเจริญเติบโตของกระดูกต้นคอโดยใช้วิธีการของ Baccetti การพัฒนาการของการสร้างฟันของฟันล่างด้านซ้ายทุกซี่ในแต่ละระยะของการเจริญเติบโตของกระดูกต้นคอประเมินจากภาพถ่ายรังสีพานอรามิค โดยใช้วิธีการของ Demirjian

ผลการศึกษา: การเจริญเติบโตของกระดูกต้นคอและพัฒนาการของฟันมีความสัมพันธ์กันโดยมีค่า Spearman rank correlation coefficients ระหว่าง 0.51-0.79 ($p<0.001$) ฟันกรามล่างแท้ซี่ที่ 2 มีความสัมพันธ์กับการเจริญเติบโตของกระดูกต้นคอมากที่สุดและฟันหน้าตัดล่างซี่กลางมีความสัมพันธ์น้อยที่สุดในระยะที่ 6 ของการเจริญเติบโตของกระดูกต้นคอพบว่าฟันกรามล่างซี่ที่ 3 สร้างรากฟันเสร็จสมบูรณ์แล้วเพียงร้อยละ 2.9 พัฒนาการของฟันกรามล่างซี่ที่ 3 ในระยะที่ปลายรากฟันใกล้จะปิดสามารถนำมาใช้บอกการการเจริญเติบโตของกระดูกต้นคอในระยะที่ 6 ได้เนื่องจากมีค่า likelihood ratio สูง (30.94)

สรุป: การพัฒนาการของฟันมีความสัมพันธ์สูงกับการเจริญเติบโตของกระดูกต้นคอ การพัฒนาการของฟันกรามล่างซี่ที่ 3 ในระยะ G สามารถใช้ทำนายในผู้ป่วยว่ามีการเจริญเติบโตของกระดูกขากรรไกรล่างที่สมบูรณ์แล้ว แต่ก็ควรใช้ร่วมกับตัวบ่งชี้ของการเจริญร่วมกับตัวอื่น